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MATERIALS EVALUATION IN THE TRI-SERVICE THERMAL RADIATION TEST --ETC(U)

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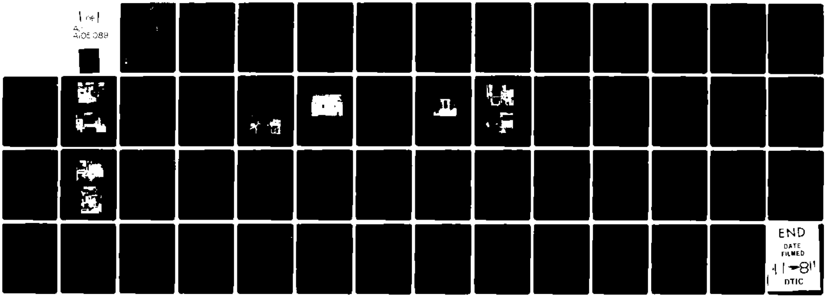

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MATERIALS EVALUATION IN THE TRI-SERVICE THERMAL RADIATION TEST FACILITY

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University of Dayton
Industrial Security Super KL-505
300 College Park Avenue
Dayton, Ohio 45469

28 February 1981

Final Report for Period 25 January 1980—28 February 1981

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Outlines facility useage during period of Jan 80-Feb 81.
Lists available instrumentation and projected useage.

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SUMMARY

The Tri-Services Thermal Nuclear Flash Test Facility for investigating the effects of thermal radiation on materials ~~has been~~ was established. The Facility is located at the USAF Wright Aeronautical Laboratories/Materials Laboratory, Wright-Patterson AFB, Ohio. The capability for irradiating specimens to intense thermal radiation, including the effects of aerodynamic loads or mechanical loads is operational. Seven thousand six hundred forty-one (7,641) tests ~~have been~~ were conducted for the Tri-Service community at this time. A large number of additional tests are scheduled during the next 12 months; additional improvements to the Facility are planned, with an emphasis on heat flux calibration techniques and on photographing specimen deterioration during the exposure to intense radiation heating.

PREFACE

This summary report covers work performed during the period from 25 January 1980 to 28 February 1981 under Defense Nuclear Agency Contract DNA001-80-C-0128. The work was administered under the direction of Mr. R. C. Webb, Contracting Officer's Representative on this contract. The contract represents a follow-on effort to Defense Nuclear Agency Contract DNA001-79-C-0106 under which the following reports were generated:

UDRI-TR-77-28, "Tri-Service Thermal Radiation Test Facility: Test Procedures Handbook," May 1977.

DNA 4488Z, "Tri-Service Thermal Flash Test Facility," Interim Summary Report, 29 March 1978.

DNA 4757F, "Tri-Service Thermal Flash Test Facility," Final Report for Period 6 August 1976-31 October 1978, 30 November 1978.

DNA 5197F, "Tri-Service Thermal Flash Test Facility," Final Report for Period 15 December 1978-15 December 1979, 15 January 1980.

The work was conducted under the general supervision of Mr. Dennis Gerdeman and the Principal Investigator was Mr. Benjamin H. Wilt. Dr. Ronald A. Servais acted as consultant and the research technician was Mr. Nicholas J. Olson.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

The University of Dayton Research Institute (UDRI) has been under contract to the Defense Nuclear Agency (DNA) since 1976 to operate the Tri-Services Thermal Flash Test Facility located at the Air Force Wright Aeronautical Laboratories (AFWAL), Wright-Patterson Air Force Base, Dayton, Ohio. Efforts in support of the DNA have included the development and operation of appropriate laboratory equipment to simulate thermal, aerodynamic, tensile, and bending loads and combinations of these loading conditions on materials of interest to the Tri-Service community.

The data accumulated through materials exposure to the combined thermal and aerodynamic or thermal and mechanical loads in the thermal flash facility can be utilized to match material performance with design criteria and as a data base for computer modeling.

1.2 OBJECTIVES

The primary objectives of the research activity have remained unchanged since the establishment of the test facility in 1976. These objectives have served to establish a materials data base from over 7,500 tests during that time and can be summarized as follows:

(1) To continue to provide the Tri-Service community with a quick-response intense radiation heating experimental capability, including the effects of aerodynamic and mechanical loads;

(2) To conduct tests for the Tri-Service community as required; and

(3) To maintain, improve, and modify the test facility between scheduled tests.

SECTION 2
TRI-SERVICE THERMAL FLASH TEST FACILITY

2.1 OVERVIEW

The original development of the Tri-Service Thermal Flash Test Facility is described in Reference 1. The facility has undergone numerous improvements to reflect the current needs of the Tri-Service community. There are still four basic experimental capabilities.

(1) Irradiation of test specimens using the Mobile Quartz Lamp Bank (MQLB);

(2) Irradiation of test specimens in aerodynamic flow using the Mobile Quartz Lamp Bank or the High Density Lamp Bank (HDLB);

(3) Irradiation of test specimens under tensile or bending mechanical creep frame loads using the MQLB; and

(4) Irradiation of test specimens under dynamic tensile MTS loads using the MQLB.

Improved facility test capabilities with the addition of the MTS equipment necessitated the upgrading of laboratory space. The thermal flash equipment was relocated during December 1980 into larger quarters for efficient utilization of test capabilities. Figure 1 illustrates the new facility layout.

Available instrumentation include radiometers for determining heat flux, thermocouples for monitoring temperatures, a pitot tube for determining flow velocities, still and movie cameras, X-Y recorders, and various electronic control devices. Limited machining facilities are available for minor specimen modification or alteration during test programs.

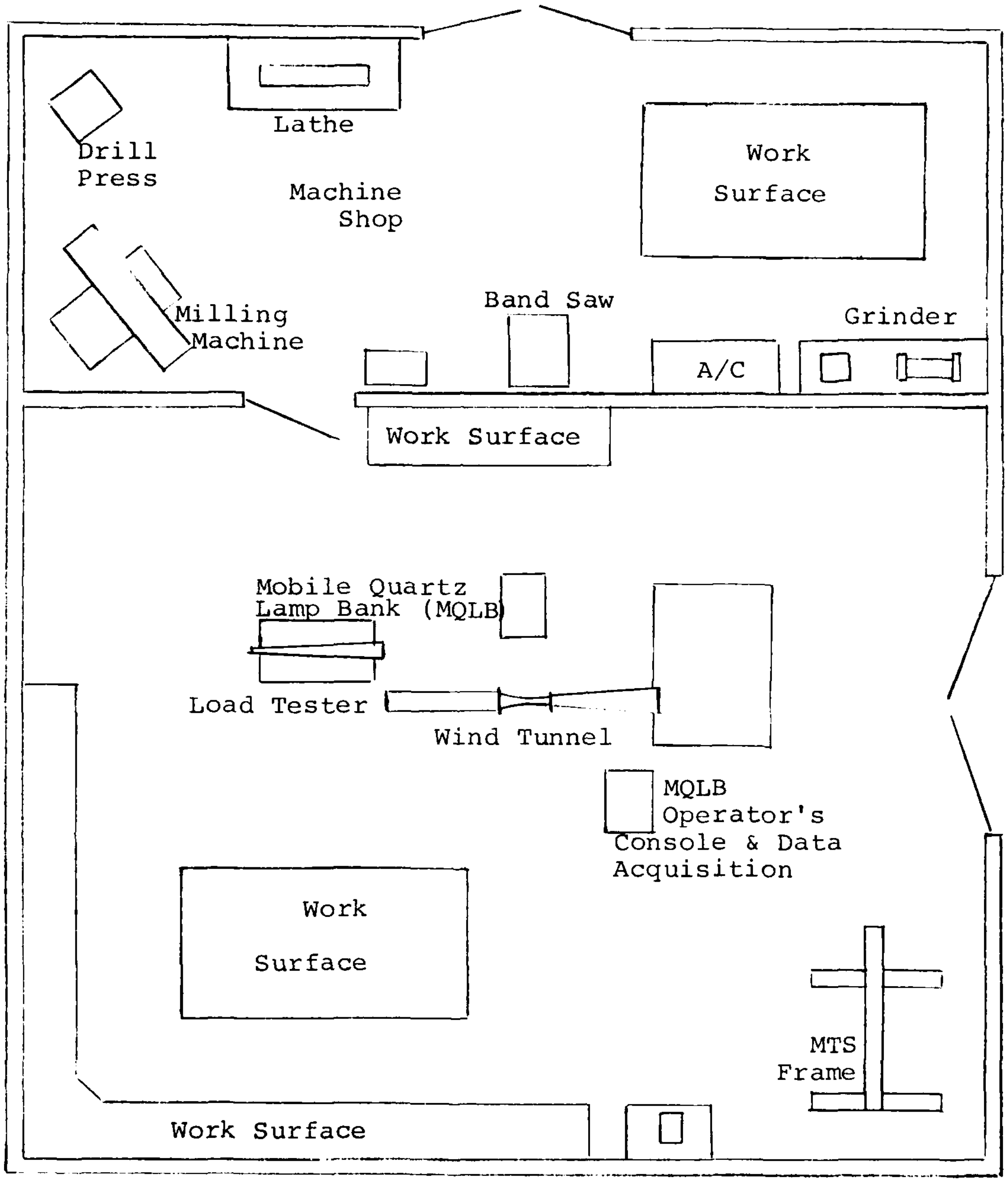

Figure 1. Tri-Service Nuclear Flash Test Facility.

2.2 NUCLEAR FLASH SIMULATION

2.2.1 Quartz Lamp Banks

The degradation of materials exposed to the radiant heating generated by a nuclear blast can vary enormously.

The intense radiation needed to simulate a nuclear flash can be produced by a series or band of tungsten filament, quartz lamps. Two banks are available in the Facility; they are designated the Mobile Quartz Lamp Bank (MQLB) and the High Density Lamp Bank (HDLB). The operational characteristics of the banks are listed in Table 1. The MQLB, shown in Figure 2, is used in conjunction with the simulation of aerodynamic or mechanical loads or as a source for radiant testing only.

TABLE 1

QUARTZ LAMP BANK SPECIFICATIONS

	MQLB	HDLB
Lamp Designation	GE/Q6M/T3/CL/HT	GE/Q6M/T3/Cl/HT
Number of Lamps	24	24
Lamp Bank Area	22 cm x 25 cm	15 cm x 25 cm
Maximum Voltage	460 vac	460 vac
Maximum Current	300 a	300 a

The MQLB approximates a one-dimensional radiation source 15 cm x 12 cm; the HDLB, shown in Figure 3, approximates a 10 cm x 12 cm one-dimensional source. The incident radiation on a test specimen is a function of the distance from the bank source, as illustrated in Figure 4.

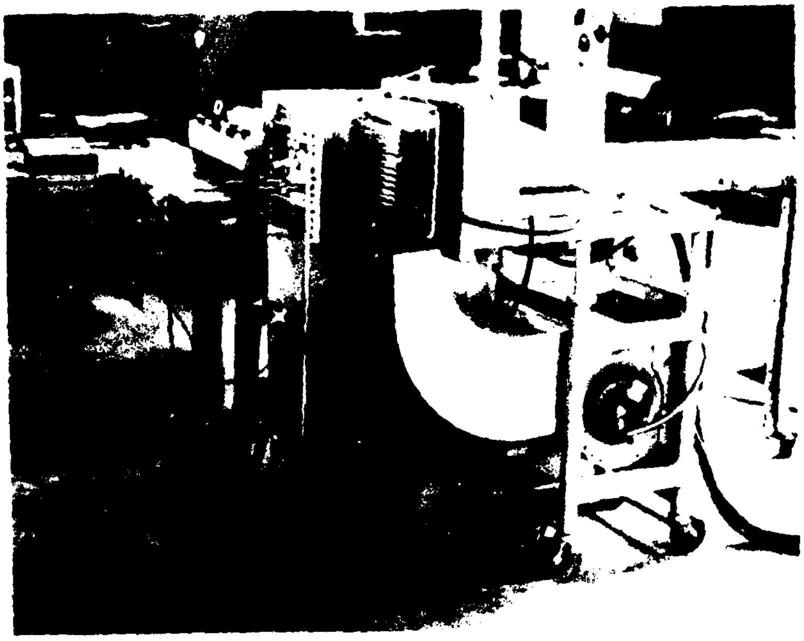

Figure 2. Mobile Quartz Lamp Bank.

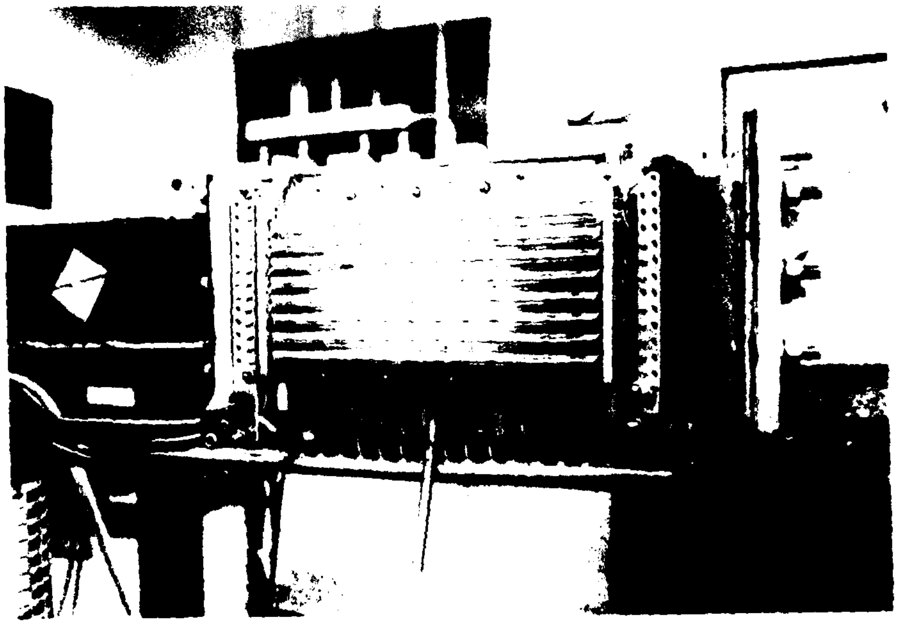

Figure 3. High Density Lamp Bank.

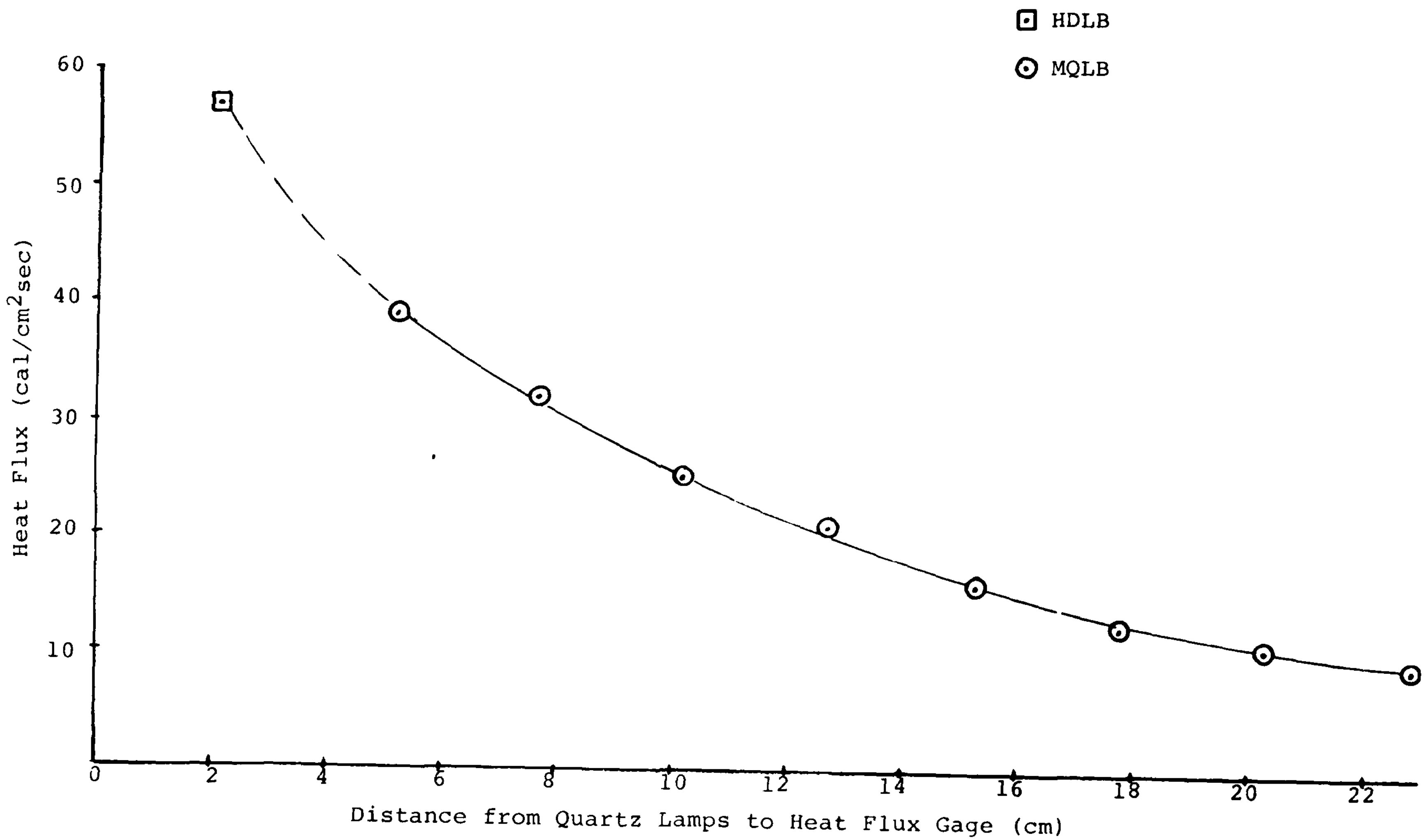

Figure 4. Radiation Heat Flux vs. Distance From Lamp Bank.

2.3 AERODYNAMIC LOAD SIMULATION

An open-circuit pull-down wind tunnel is available to simulate aerodynamic flow over specimens exposed to high intensity radiation. The wind tunnel is shown in Figure 5. A photograph of the wind tunnel test section is shown in Figure 6. The test section is 70 cm long and has a 2.38 cm x 11.43 cm cross-sectional area. The constant free-stream velocity for the section is nominally 210 m/sec with a corresponding Mach number of 0.6. The Reynolds number is 20×10^6 based on the inlet wall length. Wind tunnel exhaust gases are vented to the atmosphere through the roof of the building.

A pitot probe, manometers, and a pressure transducer are available for flow calibration, which can be supplied with each test program, as required.

The MQLB or the HDLB is used in conjunction with the wind tunnel; the beam is brought in through a quartz window which is mounted in one wall of the test section. The opposite wind tunnel test section wall holds the test specimen, which is mounted flush with the wind tunnel wall. Specimen sizes up to 22.86 cm by 10.08 cm can be accommodated. Special plates are available for the test section for mounting the various calorimeters and pitot tube for heat flux and flow calibration.

An electrically actuated shutter for the wind tunnel test configuration was designed and installed in the 70 cm test section as a first priority improvement during the previous contract effort. The shutter was installed along the centerline of the test section to take advantage of the convective cooling provided by the tunnel air flow. Lamp-to-specimen distance and, therefore, maximum heat flux available were not affected by the installation. The rapid rise and accurately controlled pulse attained with the shutter capability enhanced simulation of thermal nuclear heating. A photograph depicting shutter operation in the 70 cm test section is shown in Figure 7.

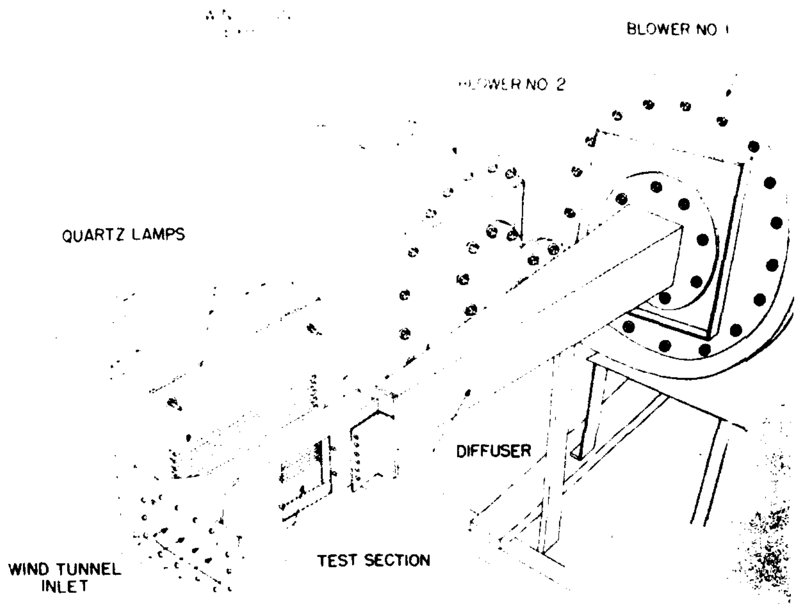

Figure 5. Wind Tunnel.

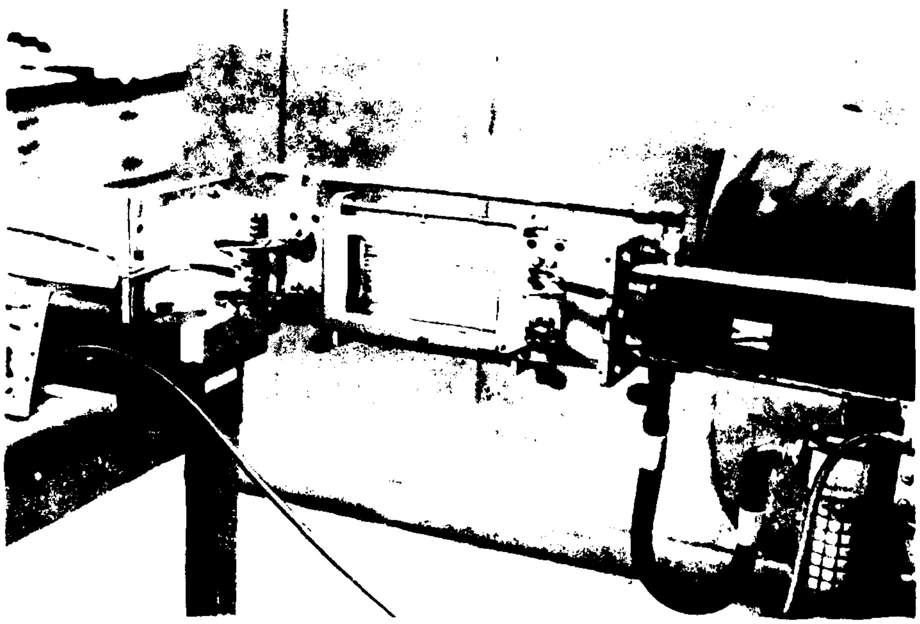

Figure 6. Wind Tunnel 70 cm Test Section.

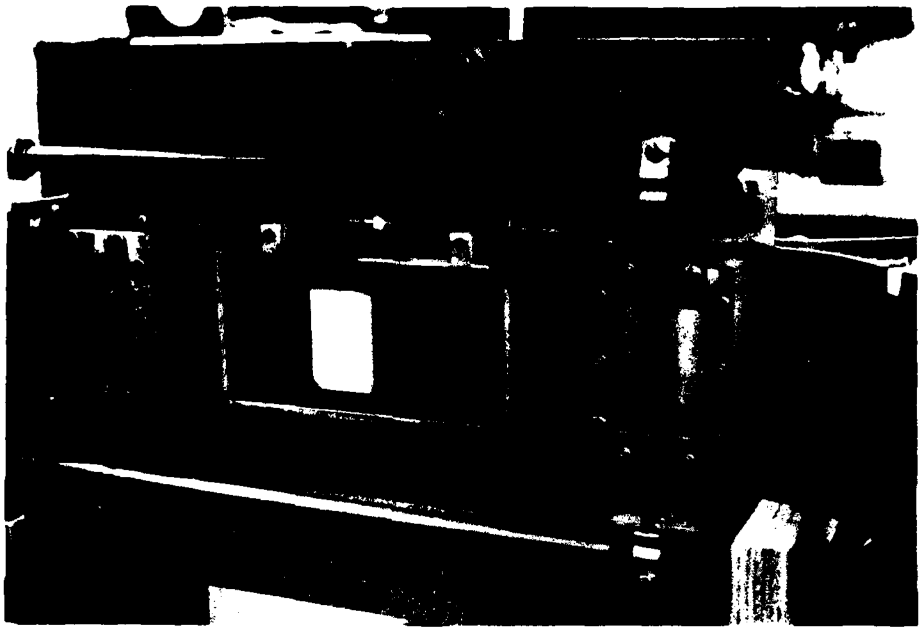

Figure 7. 70 cm Test Section Shutter.

Because of recent requirements by facility users for two-level radiant heat profiles, the shutter actuating system was replaced. Materials evaluations now require long duration, low-level irradiation followed by short duration, high level heat pulses. The solenoid in the electrical system was limited to short duration use because of overheating. An air cylinder which can be operated indefinitely was installed in place of the solenoid.

2.4 DYNAMIC LOAD SIMULATION

The ability to apply combined dynamic and thermal stresses to thermal protection materials was deemed a first priority task on this 12-month contract effort. Los Alamos Technical Associates (LATA) were responsible to DNA for designing the dynamic load capability. Fabrication and installation of a mobile frame housing the MTS system provided by LATA, and which is compatible with the quartz lamp testing, was accomplished by UDRI. Initial checkout was completed and a brief program was conducted to demonstrate system capability. The Dynamic Loading System is shown in Figure 8.

Several additions to the system will include a specimen pre-heat furnace and shutter capabilities.

2.5 MECHANICAL LOAD SIMULATION

A creep frame is available for dead weight simulation of tensile and bending loads and is shown in Figure 9. The MQLB is used as the radiation source; the exposure procedure is similar to that used in the wind tunnel. Note that mechanical and aerodynamic loads cannot be applied simultaneously at this time. Tension and bending configurations are possible. Three and four point bending is accomplished in the mechanical load frame by the addition of a yoke and fulcrum as indicated in Figure 10. Recommended specimen sizes and maximum applied loads are specified in Table 2. Strain gages and other appropriate

Figure 8. MTS Tensile Test Machine.

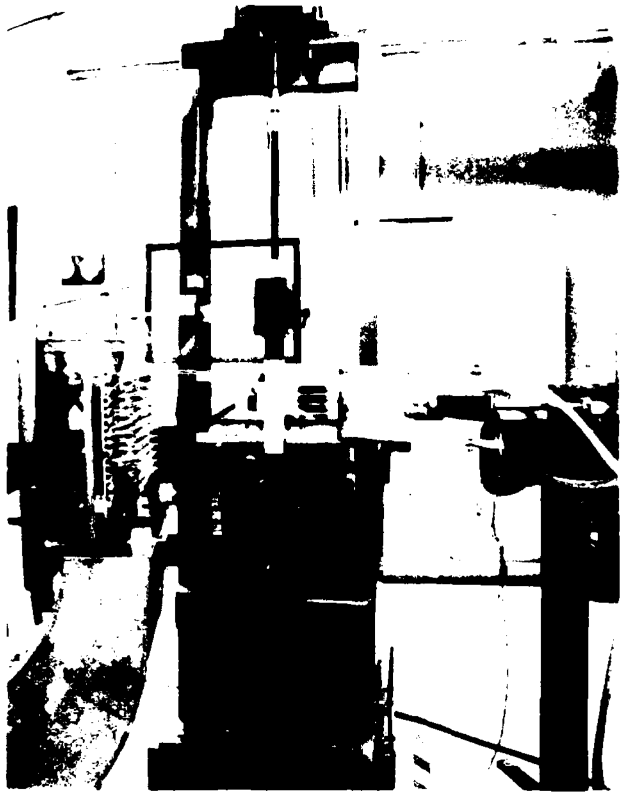

Figure 9. Mechanical Loading-Tension.

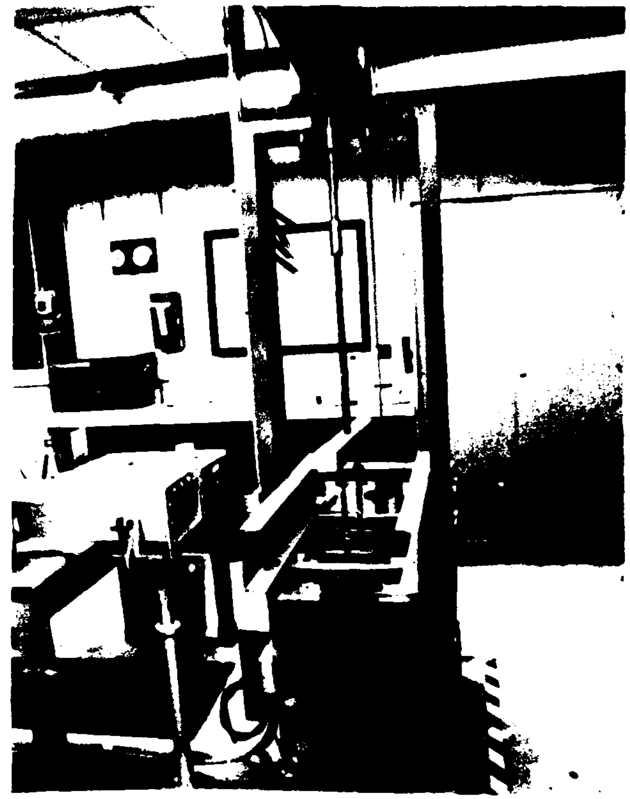

Figure 10. Mechanical Loading-Bending.

TABLE 2

RECOMMENDED MECHANICAL LOADING SPECIMEN INFORMATION

	Uniaxial Tension	Bending Tension or Compression
Specimen Size (cm)		
Width	5-7.5	5-7.5
Thickness	0.02-1.25	0.6-2.5
Length	25-60	50-75
Stress Levels (MPa)	3.5-1700	7-1400

instrumentation are mounted on test specimens in order to monitor strain as a function of time during exposure to radiation.

2.6 INSTRUMENTATION

The instrumentation required for operating the facility and which is available is summarized in Table 3. Facility users normally supply their own specimen-mounted instrumentation, such as thermocouples and strain gages. Additional details on the heat flux instrumentation and plotters which are available are given in Tables 4 and 5.

2.7 DATA ACQUISITION SYSTEM

The data acquisition system, including an LSI-11 microcomputer, is capable of producing conventional X-Y plots on-line or transmitting the digitized calibration or property data directly to the Wright-Patterson Air Force Base (WPAFB) Computing Facility for further data reduction. The output can be in the form of tabulated or plotted and labelled data. Figure 11 schematically illustrates the system. Table 6 lists the system components. The interface between the LSI-11 and the WPAFB Computing Facility was developed by Lt. Randy Rushe and is described in Reference 2.

TABLE 3

AVAILABLE INSTRUMENTATION

Application	Quantity	Instrumentation	Purpose
Quartz Lamp Banks	6	Radiometers	Heat Flux
	1	Thermac Temperature Controller	Heat Flux Control
	1	Data-Trak Controller	Heat Flux Control
Aerodynamic Load	1	$\pm$10 psi Stathem Pressure Transducer	Flow Calibration
	1	Pitot Probe Assembly	Flow Calibration
	1	Manometer	Flow Calibration
Mechanical Load	1	Wheatstone Bridge	Strain Gage
Arc Imaging Furnaces	2	Radiometers	Heat Flux
	1	Calorimeter	Heat Flux
	1	Time Controller (0.1 second minimum)	Shutter Control
General	3	X-Y-Y' Recorders	Data Recording
	1	LSI-11 Microprocessor	Data Recording
	1	35mm Nikon Still Camera	Specimen Photographs
	1	MP-4 Polaroid Still Camera	Specimen Photographs
	2	8mm Nizo Braun Movie Cameras	Specimen Photographs
	---	Various Thermocouples	Temperature
	1	L&N 8641-S Automatic Recording Pyrometer (760-6000°C)	Surface Temperature
	---	Barometer, Thermometer, Hygrometer	Ambient Conditions

TABLE 4

HEAT FLUX GAGE SPECIFICATIONS

Mfgr	Type	Model	Range	Accuracy
Medtherm	Gardon	64P-20-24	0-5 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-50-24	0-13 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-100-24	0-27 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-100-24	0-27 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-200-24	0-54 cal/cm^2sec	$\pm 3\%$
Medtherm	Gardon	64P-200-24	0-54 cal/cm^2sec	$\pm 3\%$
RdF	Gardon	CFR-1A	0-400 cal/cm^2sec	$\pm 10\%$
RdF	Gardon	CFR-1A	0-400 cal/cm^2sec	$\pm 10\%$
ADL	Calorimeter	---	50-350 cal/cm^2sec	$\pm 5\%$

TABLE 5

X-Y RECORDER SPECIFICATIONS

Mfgr	Model	Channels	Range	Response
Hewlett-Packard	7046A X-Y-Y'	2	0.2mv/cm-4v/cm	0.025-5cm/sec
Hewlett-Packard	136 X-Y-Y'	2	0.2mv/cm-20v/cm	0.05-5cm/sec
Honeywell	540 X-Y-Y'	2	0.04mv/cm-0.4v/cm	0.025-5cm/sec

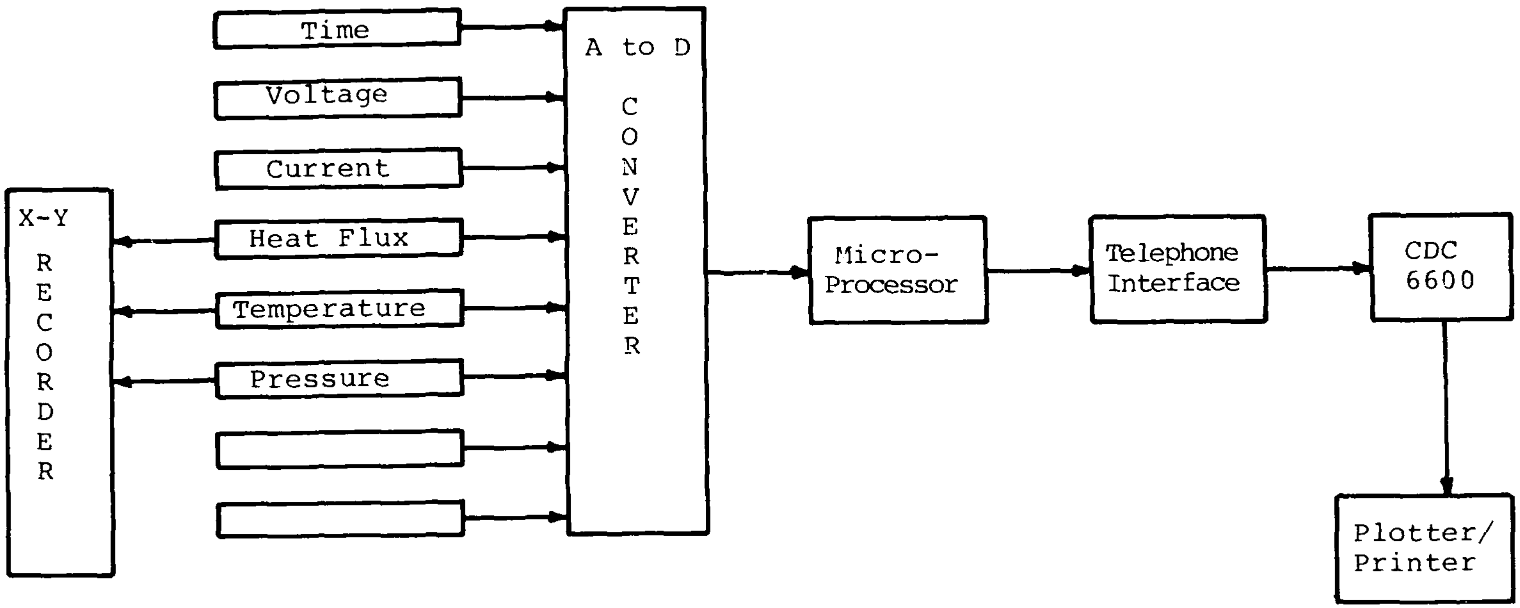

Figure 11. Data Acquisition System.

TABLE 6

DATA ACQUISITION SYSTEM COMPONENTS

Operating Controls
Wind tunnel operation
Quartz lamp operation
Quartz lamp cooling operation (blower & air)
Quartz lamp remote operation jack
Quartz lamp & shutter exposure time control
Computer reset, clock & hold operation
Controller set-point remote operation
Tri-phaser controller
Monitoring Controls
Quartz lamp power - voltage & current indicators
Wind tunnel pressure indicator
Peripheral equipment temperature indicator (10 pt.)
Shutter solenoid overheat indicator
Quartz lamp cumulative operating time indicator
Data Acquisition
LSI-11 microprocessor
Ectron differential D.C. amplifiers (8)
Power supply
Teletype
Acoustic coupler

2.8 CONTROL SYSTEM

The primary components of the laboratory (quartz lamp banks, wind tunnel, exhaust system) can be controlled and monitored from the operator console, which is shown in Figure 12. Only one operator is required for most tests. The console is located such that the operator can visually observe a test (if appropriate) and also monitor critical voltages and currents, etc. This allows the operator to abort a test if necessary. The console also controls the microcomputer and the other components of the data acquisition system with the exception of the data terminal. Figure 13 is an overview of the mobile quartz lamp bank, the wind tunnel, and the operating console.

2.9 COMPUTER MODELING

A two-dimensional thermal response computer program for predicting the thermal response of materials exposed to intense thermal radiation and aerodynamic cooling in the Tri-Service Thermal Flash Test Facility was developed by William N. Lee at Kaman AviDyne under contract to the Defense Nuclear Agency. The analysis and operating procedures are described in detail in Reference 3.

2.10 RELATED THERMAL FLASH TESTING

Under the authorization of DNA, Mr. Nicholas Olson of UDRI traveled to Kirtland AFB, New Mexico, in May 1980 to assist with instrumentation required for Thermal Flash Bag nuclear simulation testing. Mr. Olson assisted in the installation of strain gage, thermocouple, and copper slug calorimeter instrumentation on selected sections of a B-52 aircraft.

Mr. Olson had performed similar functions during previous visits to Kirtland AFB in 1979.

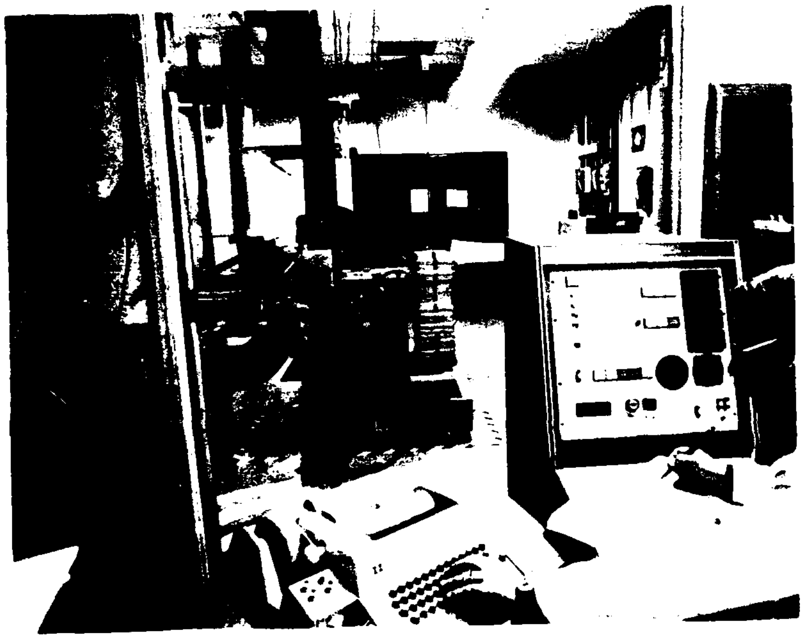

Figure 12. Console.

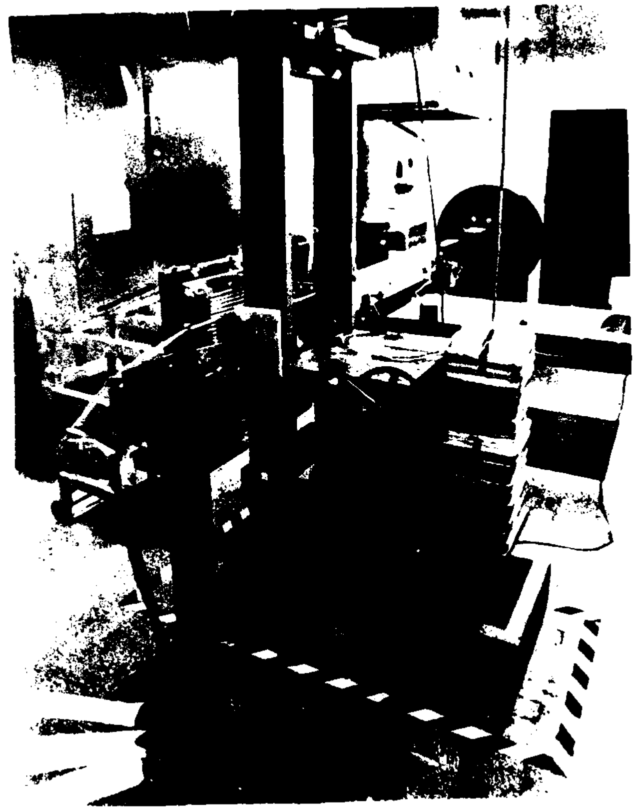

Figure 13. Thermal Flash Laboratory Overview.

SECTION 3
FACILITY UTILIZATION

3.1 TEST SCHEDULING

The Tri-Services Nuclear Flash Test Facility is available to governmental users on a no-charge basis. Test programs involving nuclear thermal flash materials performance receive priority although other tests may be accommodated; all test programs must be approved by the Defense Nuclear Agency contract monitor.

Specific details regarding test program procedures, scheduling, special testing requirements, specimen sizes, heat flux levels, etc., should be directed to the Principal Investigator and Test Director in charge of the Facility, Mr. Ben Wilt (513-229-2517). Note that the analysis of material performance must be conducted by the Facility user.

Material response tests for the Tri-Service community take precedence over all other activities associated with the operation of the Facility. That is, test requests have been scheduled at the test initiator's convenience if possible. Since most test programs are about one to five days in length, few conflicts in scheduling have arisen and few are anticipated. Based on experience, each new test program typically requires special planning and hardware (such as instrumentation and specimen mounting brackets); therefore, the more advance notice given for a particular test program the more efficiently the tests can be conducted. All test scheduling, special requirements, etc., have been and will be handled by the Test Director, Mr. Ben Wilt.

3.2 COMPLETED TEST PROGRAMS

The primary purpose of the Facility is to support the Tri-Service community with a quick-response, thermal nuclear flash, materials response testing capability. Tests which have

been conducted are summarized in Table 7. Additional information on these tests can be obtained by contacting Mr. Ben Wilt and References 4-8. The specific runs are listed in the Appendix.

3.3 PROJECTED TEST PROGRAMS

Table 8 identifies the known tests to be conducted during the next 12 months. Since the primary purpose of the Facility involves quick-response testing, it is not possible to establish a comprehensive list of all future tests at this time.

TABLE 7

COMPLETED AND CURRENT TEST PROGRAMS

Initiator	Org.	Project	Test No.	Test Dates
Alexander	AVCO	DNA	001-073	March 7-10, 1977
Alexander	AVCO	DNA	074-086	March 15, 1977
Collis	Boeing	AWACS	087-316	March 21-24, 1977
Graham	AVCO	DNA	359-416	June 6-16, 1977
Alexander	Boeing	DNA	419-574	June 20-24, 1977
Collis	AVCO	ALCM	576-677	July 19-22, 1977
Alexander	AVCO	DNA	678-772	Oct. 5-7, 1977
Grady	AFWAL	DNA	773-870	Oct. 12-22, 1977
Litvak	AFWAL	B-1	Documentary Film	March 13-24, 1978
Collis	Boeing	ALCM	871-1076	July 18-20, 1978
Sparling	Rockwell	DNA	1081-2571	July 24-Sept. 28, 1978
Worscheck	GD-Convair	ALCM	2572-2677	Oct. 2-4, 1978
Olson	UDRI	Calibration	2678-2710	Oct. 16-20, 1978
Sparling	Rockwell	DNA	2711-5753	Oct. 24-Dec. 5, 1978
Alexander	AVCO	DNA	5754-5809	Dec. 11-13, 1978
Baba	Harry Diamond	U.S. Army	5810-5881	Dec. 18-21, 1978
Olson	UDRI	Calibration	5882-5890	Jan. 22, 1979
Evans	Ballistics Research	U.S. Army	5891-5948	Jan. 23-24, 1979
Spangler	MCDAC	DNA	5949-6032	March 6-15, 1979
Rooney	AFWAL	USAF	6033-6036	March 19, 1979
Spangler	MCDAC	DNA	6037-6056	April 2, 1979
Worscheck	GD-Convair	ALCM	6057-6074	May 2, 1979
Kimerly	LATA	DNA	6075-6096	May 31-June 1, 1979
Alexander	AVCO	DNA	6097-6140	June 19-21, 1979
Baba	Harry Diamond	U.S. Army	6141-6222	June 25-27, 1979

TABLE 7 (Continued)

COMPLETED AND CURRENT TEST PROGRAMS

Initiator	Org.	Project	Test No.	Test Dates
Schmitt	AFWAL	USAF	6223-6247	June 28-29, 1979
Kimerly	LATA	DNA	6248-6264	July 2-3, 1979
Worscheck	GD-Convair	ALCM	6265-6307	July 17-19, 1979
Spangler	MCDAC	DNA	6308-6372	July 30-Aug. 2, 1979
Schmitt	AFWAL	USAF	6373-6423	August 14-16, 1979
Schmitt	AFWAL	USAF	6424-6426	August 30, 1979
Worscheck	GD-Convair	ALCM	6427-6435	September 4, 1979
Schmitt	AFWAL	USAF	6436-6438	October 3, 1979
Alexander	AVCO	DNA	6439-6449	Oct. 5-10, 1979
Olson	UDRI	DNA	6450-6466	Oct. 15-19, 1979
Rooney	AFWAL	USAF	6467-6470	Nov. 11, 1979
Kimerly	LATA	DNA	6471-6480	Dec. 4-6, 1979
Etzel	Aerojet-General	DNA	6481-6555	Dec. 10-13, 1979
Kimerly	LATA	DNA	6556-6561	Dec. 14, 1979
Hurley	AFWAL	USAF	6562-6598	Dec. 17-21, 1979
Sherwood	CAAPCO	USAF	6599-6634	Jan. 22, 1980
Sherwood	CAAPCO	USAF	6635-6639	April 2, 1980
Hurley	AFWAL	USAF	6640-6647	April 8, 1980
Kimerly	LATA	DNA	6648-6666	May 8, 1980
Tydings	AFWAL	USAF	6467	May 13, 1980
Etzel	Aerojet	MX	6468-6742	June 4-10, 1980
Henders	McDAC	MX	6743-6755	June 12, 1980
Etzel	Aerojet	MX	6756-6881	July 7-10, 1980
Walsh	Boeing-Wich.	B-52	6882-7040	July 14-18, 1980

TABLE 7 (Concluded)

COMPLETED AND CURRENT TEST PROGRAMS

Initiator	Org.	Project	Test No.	Test Dates
Kimerly	LATA	DNA	7041-7088	Aug. 20-23, 1980
Tydings	AFWAL	USAF	7089-7090	Aug. 27, 1980
Etzel	Aerojet	MX	7091-7206	Sept. 22, 1980
Church	Boeing-Wich.	B-52	7207-7211	Oct. 1, 1980
Tydings	AFWAL	USAF	7212	Oct. 14, 1980
Kimerly	LATA	DNA	7213-7232	Oct. 16-18, 1980
Rhodehamel	AFWAL	USAF	7233-7258	Nov. 4-10, 1980
Olson	UDRI	DNA	7259-7280	Nov. 11-14, 1980
Rhodehamel	AFWAL	USAF	7281-7295	Nov. 19-25, 1980
Etzel	Aerojet	MX	7296-7488	Dec. 1-5, 1980
Schuck	Collins Radio	U.S. Army	7489-7626	Dec. 15-18, 1980
Schuck	Collins Radio	U.S. Army	7627-7636	Feb. 5, 1981
Davis	Sperry Univac	GLCM	7637-7641	Feb. 17-19, 1981

TABLE 8

PROJECTED TEST PROGRAMS

Initiator	Organization	Project	Material	Date
Walsh	Rockwell	USAF	Aircraft Composites	March 1981
Etzel	Aerojet	MX	Missile Protection	April 1981
Rhodehamel	AFWAL	USAF	Graphite Epoxies	April 1981
Etzel	Aerojet	MX	Missile Protection	June 1981
Etzel	Aerojet	MX	Missile Protection	August 1981

SECTION 4
PROJECTED FACILITY DEVELOPMENT

4.1 FACILITY MAINTENANCE AND IMPROVEMENTS

Keeping the facility operational and current is an ongoing activity which is carried out between scheduled tests. Maintenance typically involves quartz lamp replacement, periodic calibration of instrumentation, and related activities. Experience has shown that this effort requires about one week per month.

Each new test program seems to extend the previous capability of the facility. This includes additional instrumentation, higher heat flux levels, etc. In order to accommodate future requirements, the time between scheduled tests and maintenance activities will be devoted to facility upgrading. These improvements are all directed toward improving the quality of the data or extending the basic facility capabilities. The improvements will be implemented by the staff as time permits, most requiring staff time rather than additional hardware purchases. The recommended improvements are listed below, categorized by priority.

All of the first priority items should be completed during the course of the contract. The portion of the second and third priority items which can be completed will depend almost entirely on the volume of materials testing work; however, we do anticipate progress in these lower priority items also.

4.1.1 First Priority Improvements

Facility Calibration - Discrepancies that exist among calibrated heat flux gages will be resolved by evaluating the various asymptotic (Gardon) gage and capacitance (slug) calorimeters under exposure to the single radiant heat source provided by the Tri-Services Thermal Flash Test Facility.

Simultaneous Aerodynamic and Mechanical Loading - The ability to simultaneously expose materials to radiant heating,

aerodynamic shear, and mechanical loading is obviously desirable. Approaches for implementing this type of test will be investigated.

Surface Phenomena Photography - Motion picture photography of surface degradation was accomplished with limited success during the current contract effort. Procedures still need refining to make surface photography a viable part of data acquisition.

Surface Temperature Pyrometry - Accurate surface temperature measurement techniques must be developed. Lack of definition of quartz lamp response and of material characteristics still inhibit adequate temperature sensing capabilities.

4.1.2 Second Priority Improvements

Quartz Lamp Wavelength Response - Spectral scanning techniques are required for the accurate determination of quartz lamp wavelength. Absorptivity, reflectivity, and transmissivity characteristics of materials evaluated in the thermal flash environment cannot accurately be determined without wavelength definition.

Test Specimen Absorptivity - An experimental method for determining the absorptivity of test materials as a function of wavelength will be developed.

4.1.3 Third Priority Improvements

Flow Improvement - The flow in the wind tunnel is not uniform, complicating the analysis of materials for which the performance is strongly dependent upon surface shear. Screens, inlet shape, and other approaches will be investigated in order to achieve a more uniform surface shear in the wind tunnel.

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2. Rushe, R., "A Microcomputer Data Acquisition System for Materials Testing," Master of Science Thesis submitted to the Air Force Institute of Technology, March 1978.

3. Lee, W. N., "TRAP-ML-A Two Dimensional Thermal Response Code Tailored for the Defense Nuclear Agency Tri-Service Thermal Radiation Test Facility," DNA 4770F, 30 November 1978.

4. Scherer, W. R. and Collis, S. E., "Nuclear Thermal Suviv-ability/Vulnerability of the E-4B," Boeing Aerospace Co. Rpt. No. D226-20380-1, March 1977.

5. "Skin Friction Drag Increase Due to Nuclear Thermal Damage," Boeing Aerospace Co. Final Report on Contract DNA001-77-C-0090, 30 September 1977.

6. Collis, S. E., "Simulated Nuclear Thermal Testing of AGM-86 Honeycomb Sandwich Structures," Boeing Aerospace Co. Rpt. No. D232-10599-3, November 1977.

7. Alexander, J. G., "Conductive Coatings for Composite Aircraft Surfaces," AVCO Systems Division, Rpt. No. AFML-TR-77-164, September 1977.

8. Collis, S. E., "Simulated Nuclear Thermal Testing of AGM-86 Nosecap Sandwich Structure and Fin/Elevon Graphite-Epoxy Composites," Boeing Aerospace Co. Rpt. (to be published).

APPENDIX

THERMAL FLASH TESTS

Run Series	Specimen Configurations: Substructures	Coatings
001-073	Aluminum 6061	WMS-0; WMS-4; WMS-7; CMS-905; WMS-0/CMS-905; WMS-4/CMS-905; WMS-7/CMS-905; 1224-0; CMS-6231
	Glass-Epoxy	WMS-0/CMS-905; WMS-7/CMS-905; CMS-905; CMS-6231
	Graphite-Epoxy	WMS-0/CMS-905; WMS-4/CMS-905; WMS-7/CMS-905; 1224-4/CMS-905; 1224-0; CMS-905
074-086	Graphite-Epoxy	WMS-0; WMS-4; WMS-7/CMS-905; WMS-7/CMS-6231; CMS-6231
087-316	Glass-Epoxy Honeycomb	MIL-C-8326; MIL-L-81352; MIL-C-83281; MIL-C-83286; Astrocoat; Fluorocarbon; Polysulfide
	Aluminum Honeycomb	MIL-C-8326; MIL-C-83286
	Graphite-Epoxy TBD Honeycomb	MIL-C-83281; MIL-C-83286
	Aluminum Sheet	MIL-C-83281; MIL-C-83286
	Magnesium Sheet	MIL-C-83281; MIL-C-83286
317-360	FACILITY MODIFICATION AND CALIBRATION	
361-412	Quartz Polyimide	Uncoated
	Graphite-Epoxy	Uncoated
419-574	Glass-Epoxy	1; 2; 3; 4A; 4B; 5A; 5B; 5C; 5D; 6; 7; 8A; 8B; 8C; 9; 9B; 10; 11; 12A; 12B; 13A; 13B; 15A; 15B; 16; 17 (Table I)
	Graphite-Epoxy	1; 2; 3; 4; 5; 5B; 5C; 6; 7; 8B; 9A; 9B; 10; 11; 12A; 12B; 13A; 13B; 15A; 16; 17 (Table I)
	Quartz Polyimide	1; 2; 3; 4A; 4B; 5A; 5B; 5C; 5E; 9A; 10; 12A; 15A; 15B; 16; 17 (Table I)
	Aluminum 6061	2; 6; 7; 12; 18; 19; 20; 21 (Table I)

APPENDIX (Continued)

THERMAL FLASH TESTS

Run Series	Specimen Configurations Substructures	 Coatings
575-677	Glass-Epoxy Honeycomb	25; 26; 28; 29; 30; 31; 32; 33 (Table I)
	Aluminum Honeycomb	25; 26; 27 (Table I)
	Aluminum Sheet	25; 26; 27 (Table I)
688-772	Glass-Epoxy	1; 2; 3; 4B; 5A; 5B; 5C; 5D; 7; 9A; 10; 10B; 15A; 24 (Table I)
	Graphite-Epoxy	4B; 6; 9A; 9C; 10; 10B; 10C; 11A; 12A; 12C; 12D; 14; 15B; 22; 23 (Table I)
	Quartz Polyimide	0; 4B; 5; 5B; 5C; 9A; 10A; 10B; 12A; 12C; 12D; 14; 15A (Table I)
773-855	Graphite-Epoxy	White polyimide; cork silicone; uncoated (All tested in tension)
	Quartz Polyimide	White polyimide; cork silicone; uncoated (All tested in tension)
856-870	Aluminum	Grey polymeric bead
871-1076	Epoxy-fiberglass Foam sandwich	34; 35; 36 (Table I)
	Epoxy-fiberglass Honeycomb sandwich	35; 37 (Table I)
	Graphite-epoxy	38; 39; 40 (Table I)
	Natural polyethylene with honeycomb core	No coating
	White polyethylene with honeycomb core	No coating
	Delrin with Flexcore Honeycomb	No coating
	Nylon with Flexcore Honeycomb	No coating

APPENDIX (Continued)

THERMAL FLASH TESTS

Run Series	Specimen Configurations Substructures	Coatings
1081-2571	Honeycomb Substructure	41; 42; 43; 44; 45; 46; 47; 48; 49; 50; 51; 52; 53; 54 (Table I)
2572-2677	Aluminum 7075	55; 56; 57; 58; 59; 60; 61; 62; 63; Anodize (Table I)
	Glass-Epoxy	55; 56; 57; 58; 59; 60; 61; 62; 63; Uncoated (Table I)
2678-2710	FACILITY MODIFICATION AND CALIBRATION	
2711-5753	Honeycomb Substructure	41; 42; 43; 44; 45; 46; 47; 48; 49; 50; 51; 52; 53; 54 (Table I)
5754-5809	Graphite-Epoxy	1; 2; 3; 4A; 4B; 5A; 5B; 6; 10A; 10B; 10C; 14; 15A; 15B; 16; 17 (Table I)
	Quartz Polyimide	1; 2; 3; 4A; 4B; 5A; 5B; 6; 10A; 10B; 10C; 14; 15A; 15B; 16; 17 (Table I)
5810-5881	Fiber Optics	64; 65; 66; 67; 68 (Table I)
	Twisted Pair and Coaxial Electrical Cables	64; 65; 66; 67; 68 (Table I)
5882-5890	FACILITY CALIBRATION	
5891-5948	1060 Cold Rolled Steel	69; 70; 71; 72; 73; 74; 75; 76; 77; 78 (Table I)
5949-6032	Kevlar-Epoxy	79; 80; 81; 82; 83; 84; 85; 86; 87; 88; 89; 90; 91; 92; 93; 94 (Table I)
	Motorcase	79; 80; 81; 82; 83; 84; 85; 86; 87; 88; 89; 90; 91; 92; 93; 94 (Table I)
6033-6036	Aluminized Fabric	No coating
6037-6056	Vamac	No coating
	Viton	No coating

APPENDIX (Continued)

THERMAL FLASH TESTS

Run Series	Specimen Configurations Substructures	Coatings
6057-6074	Aluminum	55; 56; 57; 58; 59; 60; 61; 62; 63 (Table I)
	Epoxy/Fiberglass	55; 56; 57; 58; 59; 60; 61; 62; 63 (Table I)
6075-6096	Polypropylene	No coating
6096-6140	Graphite-Epoxy	1; 2; 3; 4A; 4B; 5A; 5B; 6; 10A; 10B; 10C; 14; 15A; 15B; 16; 17 (Table I)
	Quartz Polyimide	1; 2; 3; 4A; 4B; 5A; 5B; 6; 10A; 10B; 10C; 14; 15A; 15B; 16; 17 (Table I)
6141-6222	Fiber Optics	64; 65; 66; 67; 68 (Table I)
	Twisted Pair and Coaxial Electrical Cables	64; 65; 66; 67; 68 (Table I)
6223-6247	Aluminum	95; 96; 97; 98; 99; 100; 101; 102; 103; 104; 105 (Table I)
6248-6264		106; 107; 108; 109 (Table I)
6265-6307	Aluminum	55; 56; 57; 58; 59; 60; 61; 62; 63 (Table I)
	Epoxy/Fiberglass	55; 56; 57; 58; 59; 60; 61; 62; 63 (Table I)
	Polycarbonate	55; 56; 57; 58; 59; 60; 6o; 62; 63 (Table I)
	Quartz-Epoxy	55; 56; 57; 58; 59; 60; 61; 62; 63 (Table I)
6308-6372	Vamac	No coating
6373-6426	Aluminum	110; 111; 112; 113; 114; 115; 116; 117; 118; 119; 120; 121; 122; 123; 124 (Table I)
6427-6435	Teflon-Epoxy	55; 56 (Table I)

APPENDIX (Continued)

THERMAL FLASH TESTS

Run Series	Specimen Configurations Substructures	Coatings
6436-6438	Epoxy/Fiberglass	125 (Table I)
6439-6449	Quartz Polyimide	4A; 4B (Table I)
6450-6466	FACILITY CALIBRATION	
6467-6470	Aluminized Tape	No coating
6471-6480	FACILITY CALIBRATION	
6481-6555		126; 127; 128; 129; 130; 131; 132; 133 (Table I)
6556-6561	FACILITY CALIBRATION	
6562-6598	Aluminum	95; 96; 97; 98; 99; 100; 101; 102; 103; 104; 105; 110; 111; 112; 113; 114; 115; 116 (Table I)
6599-6639	Quartz-Polyimide/ Graphite Epoxy	134; 135; 136; 137; 138; 139; 140; 141; 142; 143 (Table I)
6640-6647	Aluminum	144; 145; 146; 147; 148; 149 (Table I)
6648-6666	FACILITY CALIBRATION	
6667	Aluminized Tape	No coating
6668-6742	Aluminum	NBR/EDPM blends, Vamac
6743-6755	Wind tunnel convective cooling evaluation	
6756-6881	Aluminum	NBR/EDPM blends
6882-7040	Glass-Epoxy Honeycomb	150; 151; 152 (Table I)
7041-7058	FACILITY CALIBRATION	

APPENDIX (Concluded)

THERMAL FLASH TESTS

Run Series	Specimen Configurations: Substructures	Coatings
7059-7088	FACILITY CALIBRATION	
7089-7090	Aluminized Tape	No coating
7091-7206	Aluminum	Ne blends; Duroid (AVCO); Cork (Thiokol); Silicone (Thiokol); Vamac 25
7207-7211	Quartz Polyimide	No coating
7212	Aluminized Tape	No coating
7213-7232	DYNAMIC LOAD CHECKOUT	
7233-7258	Surface Temperature Determinations	
7259-7280	FACILITY CALIBRATION	
7281-7295	Quartz Polyimide	No coating
7296-7488	Aluminum	153; 154; 155; 156; 157; 158; 159; 160; 161; 162; 163; 164; 165; 167 (Table I)
7489-7636	Electrical Hardware	Switch faces; keyboard displays; digital panel meters; LED displays, connectors
7637-7641	Fiber-Optics	Kevlar strength shields, EDM Galite, PPP non-woven Kevlar

TABLE 9

TABLE OF MATERIALS

1	Two-layer anti-static white polyurethane
2	Single-layer aluminized polyurethane
3	White MIL-C-83286 over aluminized polyurethane
4A	Dow 808 white silicone, 50 PVC titania
4B	Dow 808 white silicone, 25 PVC titania
5A	Three layer white fluorocarbon, 40 PVC titania plus fibers
5B	Three layer white fluorocarbon, 25 PVC titania plus fibers
5C	Three layer fluorocarbon erosion coating, 25 PVC titania plus fibers
5D	Three layer fluorocarbon erosion coating, 40 PVC titania plus fibers
6	Bonded copper foil, 2 Mil
7	Flame sprayed aluminum
8A	Bonded polyester film, 10 Mil
8B	Bonded TFE teflon film, 10 Mil
8C	Bonded UHMW polyethylene film, 10 Mil
9A	Bonded cork silicone, 20 Mil
9B	Bonded cork silicone, 50 Mil
9C	Cork silicone, 10 Mil
10A	Epoxy-polyimide white ablative paint
10B	Epoxy-polyimide flexible white, 6 Mil
10C	Epoxy-polyimide flexible white, 10 Mil
11	Grafoil stitched package
12A	Bonded RTV 655 silicone, 20 Mil
12B	Bonded RTV 655 silicone, 50 Mil
12C	Modified RTV 655, white, sprayed, 10 Mil
12D	Modified RTV 655, white, sprayed, 3 Mil
13A	Bonded silastic 23510 white silicone, 20 Mil
13B	Bonded silastic 23510 white silicone, 50 Mil
14	RTV-655, 3 Mil over cork silicone, 10 Mil
15A	134/KHDA polyurethane erosion coating, 5 PVC titania
15B	134/KHDA polyurethane erosion coating, 25 PVC titania

TABLE 9

TABLE OF MATERIALS (Continued)

16	Desoto 10A grey polyurethane topcoat over aluminized polyurethane
17	Bostic dark grey polyurethane over aluminized polyurethane
18-21	Grey polyurethane
22	White RTV 655, 3 Mil over conductive RTV 3 Mil
23	Bonded aluminum foil, 2.4 Mil
24	Bonded aluminum foil with topcoat, 2.4 Mil
25	MIL-P-23377 primer plus white MIL-C-83286 enamel (Desoto)
26	Same as "25" except thicker enamel
27	Same as "25" except very thick enamel
28	Astrocoat system; primer plus white 8001 erosion coating plus white (non-yellowing) 8004 topcoat
29	Same as "28" but the 8001 coating is thicker
30	Astrocoat system; primer plus white (non-yellowing) 8004 topcoat
31	Astrocoat system; primer plus white 8001 erosion coating plus black 8003 antistatic topcoat
32	Same as "31" except thicker 8001 coating
33	Same as "25" except DEFT white enamel per MIL-C-83286
34	2-ply 120 fabric prepreg
35	2-ply 181 fabric prepreg
36	3-ply 181 fabric prepreg
37	5-ply 120 fabric prepreg
38	5-ply skin with chopped fiber-epoxy
39	2-ply skin with chopped fiber-epoxy

TABLE 9

TABLE OF MATERIALS (Continued)

40	5-ply skin with chopped graphite fiber bonded to titanium
41	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 7781 glass reinforced F-161 epoxy (3, 4, 5, and 6 plies)
42	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 7781 glass reinforced CE-9000 epoxy (3, 4, 5, and 6 plies)
43	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 7781 glass reinforced F-178 addition polyimide (3, 4, 5, and 6 plies)
44	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 7781 glass reinforced 2272 addition polyimide (3, 4, 5, and 6 plies)
45	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 581 quartz reinforced F-161 epoxy (3, 4, 5, and 6 plies)
46	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 581 quartz reinforced F-178 addition polyimide (3, 4, 5, and 6 plies)
47	MIL-C-83286 white polyurethane, MIL-P-83277 primer over T-300 graphite reinforced 5208 epoxy (3, 4, 5, and 6 plies)
48	MIL-C-83286 white polyurethane, MIL-P-83277 primer over AS graphite reinforced 3501-5A epoxy (3, 4, 5, and 6 plies)
49	MIL-C-83286 white polyurethane, MIL-P-83277 primer over AS graphite reinforced 934 epoxy (3, 4, 5, and 6 plies)
50	MIL-C-83286 white polyurethane, MIL-P-83277 primer over AS graphite reinforced F-178 addition polyimide (3, 4, 5, and 6 plies)
51	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 181 Kevlar reinforced 5208 epoxy (3, 4, 5, and 6 plies)
52	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 181 Kevlar reinforced F-161 epoxy (3, 4, 5, and 6 plies)
53	MIL-C-83286 white polyurethane, MIL-P-83277 primer over 181 Kevlar reinforced 934 epoxy (3, 4, 5, and 6 plies)
54	MIL-C-83286 white polyurethane, MIL-P-83277 primer over boron-epoxy (3, 4, 5, and 6 plies)

TABLE 9

TABLE OF MATERIALS (Continued)

55	MIL-P-23377 primer
56	MIL-C-81773 coating 37875 over MIL-P-23377 primer
57	MIL-C-81773 coating 36622 over MIL-P-23377 primer
58	MIL-C-81773 coating 36314 over MIL-P-23377 primer
59	MIL-C-81773 coating 17875 over MIL-P-23377 primer
60	MIL-C-83286 coating 30140 over MIL-P-23377 primer
61	Mask 10A over MIL-P-23377 primer
62	Mask 10A over MIL-C-81773 coating 17875 over MIL-P-23377 primer
63	Mask 10A over MIL-C-81773 coating 37875 over MIL-P-23377 primer
64	Polyethylene
65	Polyurethane
66	Teflon
67	Polyvinylchloride
68	Rubber
69	Army Systems Camouflage MIL-E-52798A over TTP-636 primer
70	Army Systems Camouflage MIL-E-52835A over TTP-636 primer
71	Army Systems Camouflage MIL-E-52929 over TTP-636 primer
72	Army Systems Camouflage MIL-E-52909 over TTP-636 primer
73	Army Systems Camouflage MIL-E-52926 over TTP-636 primer
74	Army Systems Camouflage MIL-E-52798A over TTP-664 primer
75	Army Systems Camouflage MIL-E-52835A over TTP-664 primer
76	Army Systems Camouflage MIL-E-52929 over TTP-664 primer
77	Army Systems Camouflage MIL-E-52909 over TTP-664 primer
78	Army Systems Camouflage MIL-E-52926 over TTP-664 primer

TABLE 9

TABLE OF MATERIALS (Continued)

79	Vamac 25-1.5, 2.5, and 3.5 mm thick
80	Viton 2B12-1.5, 2.5, and 3.5 mm thick
81	Vamac, 0.635 mm over Vamac-Silica, 2.865 mm
82	Vamac-Silica, 3.5 mm thick
83	NBR, 3.5 mm thick
84	Motorcase, 4.2 mm over motorcase, 7.7 mm
85	Vamac, 2.5 mm over Vamac Foam, 1.0 mm
86	Vamac, 2.5 mm over Light Vamac Foam, 1.0 mm
87	Vamac, 1.5 mm over Vamac Foam, 2.0 mm
88	Viton, 2.5 mm over Viton Foam, 1.0 mm
89	Viton, 1.5 mm over Viton Foam, 2.0 mm
90	Viton, 2.5 mm over Light Viton Foam, 1.0 mm
91	Low carbon Vamac, 3.5 mm
92	Low resistivity Vamac, 3.5 mm
93	KPN
94	White Viton over Viton, 2.0 mm
95	IR Silicone Camouflage, Black, F1
96	IR Silicone Camouflage, Green, F2
97	IR Silicone Camouflage, White, F3
98	IR Silicone Camouflage, Yellow, F4
99	IR Silicone Camouflage, Blue, F5
100	IR Silicone Camouflage, White, F6
101	IR Silicone Camouflage, Yellow, F7
102	IR Silicone Camouflage, Red, F8

TABLE 9

TABLE OF MATERIALS (Continued)

103	IR Silicone Camouflage, Black, F9
104	IR Silicone Camouflage, Yellow, F10
105	IR Silicone Camouflage, Yellow, F11
106	Vamac 25
107	Vamac 1 and 2
108	Vamac (GD 151)
109	Royacril 1
110	IR Silicone Camouflage, White, F12-F15
111	IR Silicone Camouflage, Green, F16
112	IR Silicone Camouflage, Black, F17
113	IR Silicone Camouflage, Green, F18
114	IR Silicone Camouflage, Green, F19
115	IR Silicone Camouflage, Blue, F20
116	IR Silicone Camouflage, Blue, F21
117	IR Silicone Camouflage, Grey, F22-F25
118	IR Silicone Camouflage, Green, F26
119	IR Silicone Camouflage, Lt. Green, F27
120	IR Silicone Camouflage, Tan, F28
121	IR Silicone Camouflage, Grey, F29
122	IR Silicone Camouflage, Tan, F30
123	IR Silicone Camouflage, Black, F31
124	IR Silicone Camouflage, Dk. Green, F32-33

TABLE 9

TABLE OF MATERIALS (Continued)

125	Polyurethane, CAAP
126	Vamac 25, Lab
127	Vamac 25, PP2-B
128	Vamac 25, PP2-E
129	Vamac 25, PP2-B/Sp
130	Vamac 25, PP2-E/Sp
131	Vamac 25, Lab/Sp
132	Vamac 32, Lab
133	Vamac 32, PP2-B
134	White fluoroelastomer, Type II lusterless
135	White fluoroelastomer, over Al0 primer
136	White fluoroelastomer, over black anti-static primer, Type III
137	White fluoroelastomer, with Cd/Se gray fluoroelastomer No. 36622
138	White fluoroelastomer, with No. 36270 Cd/Se fluoroelastomer (gray)
139	White fluoroelastomer, with No. 30219 Pb/Cr fluoroelastomer (brown)
140	White fluoroelastomer, with No. 30219 Cd fluoroelastomer (brown)
141	White fluoroelastomer, with No. 34154 Cd fluoroelastomer (green)
142	Tungsten oxide fluoroelastomer - 5 PVC
143	Tungsten oxide fluoroelastomer - 10 PVC
144	IR silicone camouflage, Green, F47-3A
144	IR silicone camouflage, Green, F47-3B

TABLE 9

TABLE OF MATERIALS (Concluded)

146	IR silicone camouflage, Green, F48-3A
147	IR silicone camouflage, Green, F48-3B
148	IR silicone camouflage, Red, F51-3A
149	IR silicone camouflage, Red, F51-3B
150	MIL-C-83286 white polyurethane (5 mil), MIL-P-23377 primer
151	MIL-C-83286 white polyurethane (10 mil), MIL-P-23377 primer
152	MIL-C-83286 white polyurethane (2 mil) over MIL-C-84445 white rain erosion Astrocoat (10 mil), Chem-glaze No. 9922 primer
153	External protection materials, NE 36-A
154	External protection materials, 370-9966A
155	External protection materials, 370-9966A (single-ply)
156	External protection materials, 11 NE
157	External protection materials, V34Y
158	External protection materials, V22A
159	External protection materials, V25
160	Carbon felt
161	RTV 560
162	RTV 560 - 50 percent porosity
163	RTV 560 - maximum porosity
164	RS 1305
165	RS 1305 - 50 percent porosity
166	RS 1305 - maximum porosity
167	RS 1305 loaded - 90 percent porosity

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